

GOLD BRAZE INVESTIGATION
AS APPLICABLE TO
MULTICYCLE METALLIC REVERSING BLADDERS

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California Institute of Technology
Jet Propulsion Laboratory
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Pasadena, California 91103

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Prepared by:

ARDE, INC.
580 Winters Avenue
Paramus, New Jersey 07652

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I ABSTRACT

As part of the effort under Contract 951898, a program was undertaken to establish the technology necessary to utilize a gold alloy as the braze material in the fabrication of an 18" diameter, wire reinforced multicycle stainless steel reversing bladder.

In performance of the above, a literature survey was conducted, flat plate specimens were fabricated and tested as were two (2) 11.5 inch diameter bladder structural models.

The ARDE gold braze evaluation program was conducted in conjunction with a propellant compatibility screening evaluation at the Jet Propulsion Laboratory.

The results of the braze evaluation program showed that structurally adequate brazed joints between reinforcing wires and bladder shell can be made utilizing gold brazing alloys compatible with the projected propellants (N_2O_4 and N_2H_4)

II INTRODUCTION

There is a need for a braze material which can provide a structurally satisfactory attachment of the stainless steel reinforcing wires to the stainless steel shell of a multicycle hoop reinforced expulsion bladder and at the same time be compatible with various oxidizers and fuel for long term storage applications. To date, copper has been utilized successfully in the brazing of the wires to the bladder membrane since it exhibits good ductility while providing sufficient structural strength. However, copper, as a rule is not compatible with some of the more exotic propellants in use today. The propellants to be stored and expelled by the bladder-tank assembly of this program (N_2O_4 and N_2H_4) for example, vigorously attack copper. Hence, there is a need to develop a system in which all the materials are compatible even though the braze material and the contained fluid are physically separated by the bladder shell. A fully compatible system would then provide added reliability in the event that any of the contained oxidizer or propellant were inadvertently allowed to come in contact with the braze material on the gas side of the bladder either through negligence or the permeation of the fluid through an undetected flaw in the bladder shell.

III SUMMARY

The program undertaken resulted in the selection of a gold braze alloy which is compatible with both nitrogen tetroxide (N_2O_4) and hydrazine (N_2H_4) as well as the development of the techniques and the establishment of the brazing parameters enabling the use of the alloy in the fabrication of stainless steel bladders.

In performance of this program, the effort was undertaken in four phases as follows:

1. A literature survey was conducted.
2. Flat plate specimens were fabricated and evaluated.
3. Compatibility testing was conducted.
4. Structural bladder models were fabricated and tested.

A. Literature Survey

A literature survey was conducted which lead to the selection of three (3) candidate alloys. The alloys selected for evaluation were Nicoro 80 with a composition of 81.5% Gold, 16.5% Copper and 2.0% Nickel manufactured by the Western Gold and Platinum Company; Engaloy 238 with a composition of 80% Gold and 20% Copper and Engaloy 255 with a composition of 82% Gold and 18% Nickel, both of which are manufactured by Englehard Industries.

B. Flat Plate Specimens

Sixteen (16) flat plate peel test specimens were fabricated and evaluated during the course of the investigation. The results of this phase of the program indicated that each of the three (3) alloys selected when brazed at a temperature of $1900 \pm 25^{\circ}\text{F}$ in a hydrogen atmosphere would provide a ductile braze joint exhibiting good wetability with negligible diffusion into the parent material. The results achieved with each of the alloys was comparable to past experience with specimens brazed with pure copper.

C. Compatibility Specimens

Representative samples which had been cut from the flat plate specimens from each of the alloys were immersed in both the oxidizer (N_2O_4) and the fuel (N_2H_4) at the Jet Propulsion Laboratory in order to ascertain the compatibility of the alloys.

The investigation indicated that each of the alloys evaluated was acceptable for use with either of the propellants. The relative evaluation of each with respect to the other indicated that the alloys were equivalent from a compatibility standpoint with the Nitrogen Tetroxide and that the Engaloy 255 appears to be best with the Hydrazine whereas the Nicoro 80 was the least relatively speaking.

D. Structural Bladder Models

Two (2) 11.5 inch diameter structural bladder models were fabricated utilizing the Engaloy 255 alloy as the braze material.

The evaluation of the bladders consisting of reversal tests in a water pressurized test rig indicated that the performance of the Engaloy 255 alloy was comparable to pure copper and in no way detrimental to the performance or operation of the bladder.

IV DISCUSSIONA. Literature Survey

A literature survey was conducted utilizing available information which lead to the selection of three (3) candidate gold braze alloy compositions.

The survey was based on finding an alloy which exhibited good ductility, good flow and wetability characteristics while processing high strength as well as being compatible with Nitrogen Tetroxide and Hydrazine propellants.

The survey revealed three (3) alloy compositions as listed below which appeared to possess the desirable characteristics. The alloy compositions were:

1. 82% Au, 18% Ni
2. 80% Au, 20% Cu
3. 81.5% Au, 16.5% Cu, 2% Ni

A bibliography of the literature surveyed is contained in Appendix A.

B. Flat Plate Specimens

A series of flat plate specimens were fabricated in order to evaluate the various candidate alloys with respect to wetability as a function of temperature, ductility and strength.

The specimens were fabricated using .008 thick 304L stainless steel bladder material and .094 diameter 308 stainless steel wire in accordance with the dimensions as indicated in Figure 1. A representative photograph of a typical specimen is also shown in Figure 2.

The brazing was accomplished in a hydrogen atmosphere utilizing a ten (10) minute hold time at temperature. The braze alloy was applied in the form of wire with the specimens divided into groups. One group was brazed using .010 diameter wire, and the other group brazed with .013 diameter wire. A temperature of $1750 \pm 25^{\circ}\text{F}$ was selected as the initial brazing temperature based on vendor published data for the liquidus and solidus temperatures for each of the alloys being evaluated. These temperatures are tabulated in Table I for each of the candidate alloys.

TABLE I

<u>Alloy</u>	<u>Composition</u>	<u>Liquidus Temperature</u>	<u>Solidus Temperature</u>
Nicoro 80	81.5% Au - 16.5 Cu - 2.0 Ni	1697°F	1670°F
Engaloy 238	80% Au - 20% Cu	1670°F	1666°F
Engaloy 255	82% Au - 18% Ni	1742°F	1742°F

The initial specimens brazed utilized the Nicoro 80 alloy. However, the temperature was insufficient and no flow of the braze material was achieved. The temperature was subsequently increased to $1825 \pm 25^{\circ}\text{F}$ with excellent results. A photograph of the micro-section is provided in Figure 3, illustrating the fillet which

FLAT PLATE SPECIMEN

.008 Thick
304L Stainless Steel

.093 Diameter
308 Stainless Steel

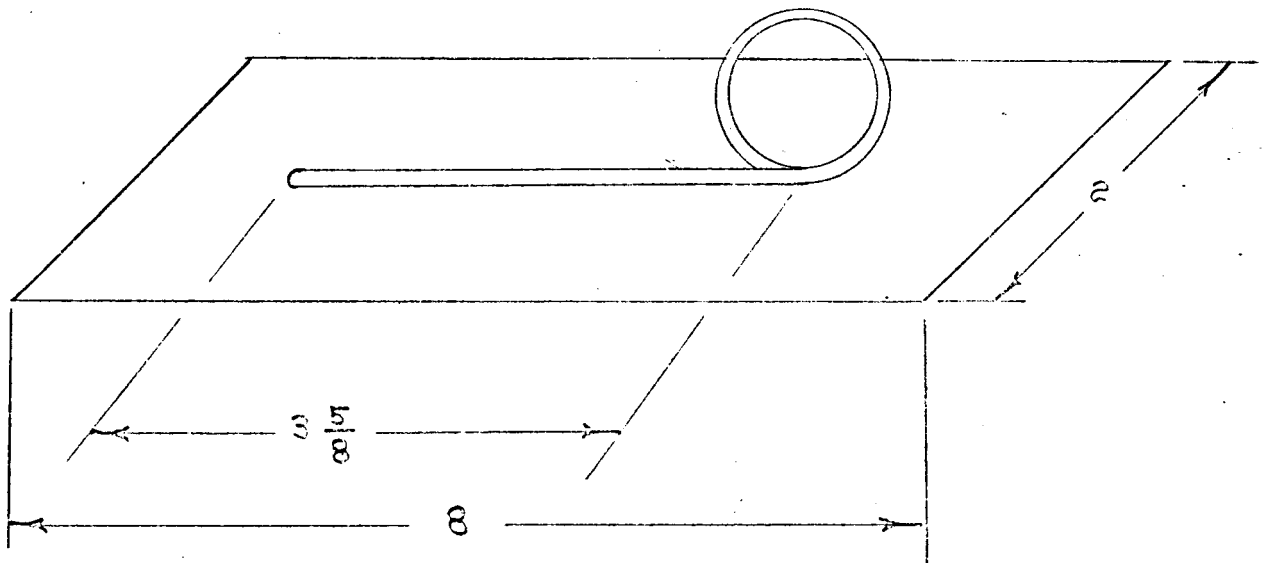
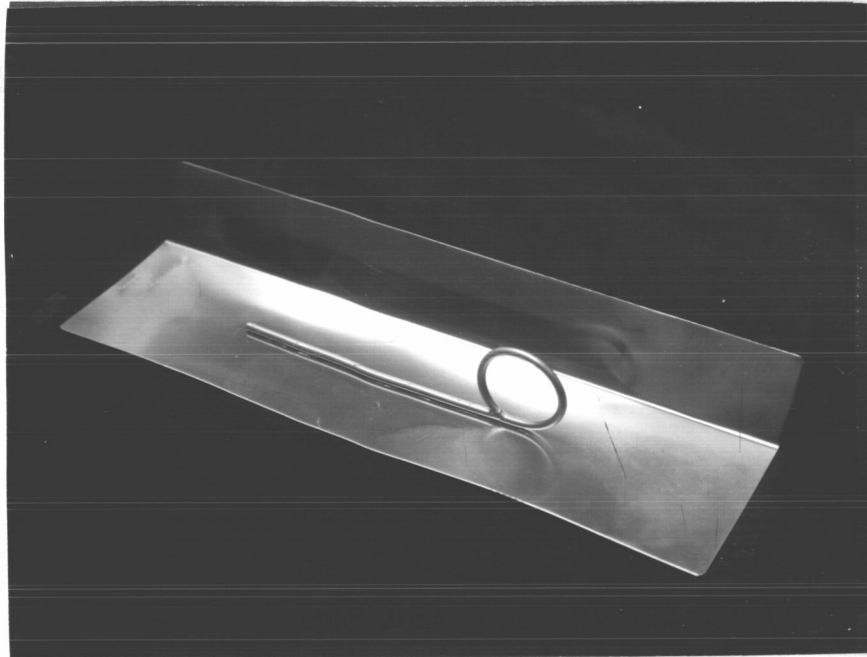
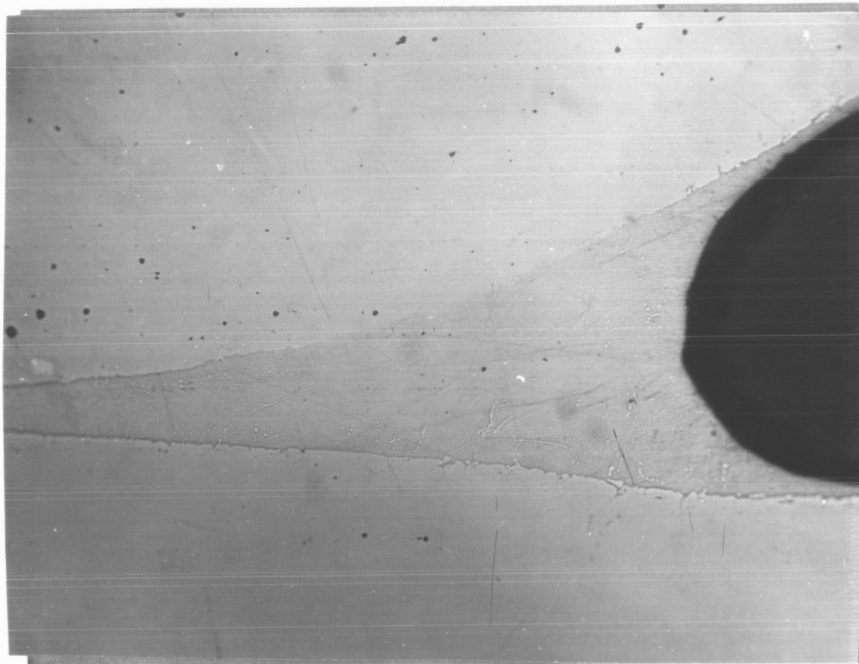


FIGURE 1



Flat Plate Specimen

FIGURE 2



Micro Cross Section of Specimen
Brazed with Nicoro 80 Alloy

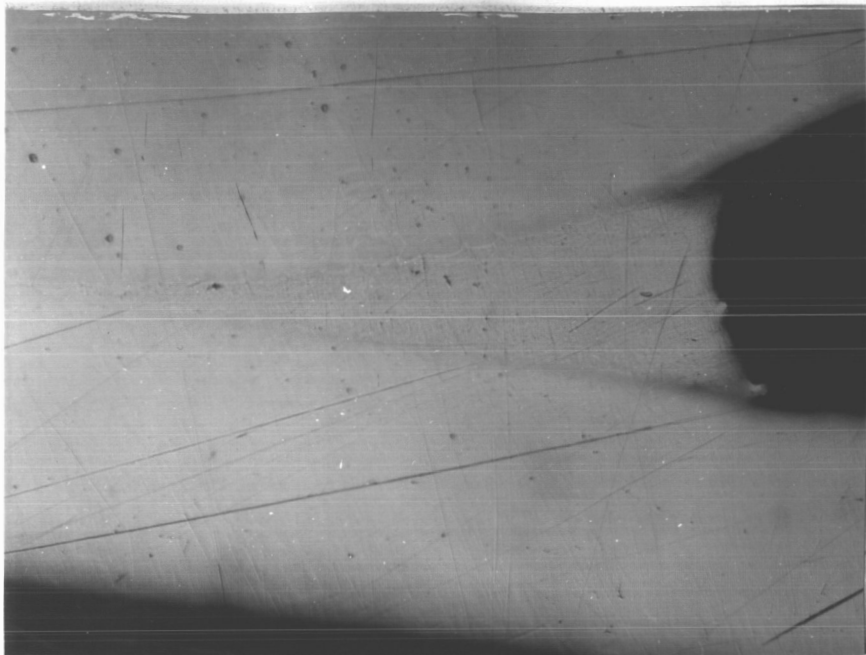
Brazing Temperature - 1825°F
Magnification - 200X

FIGURE 3

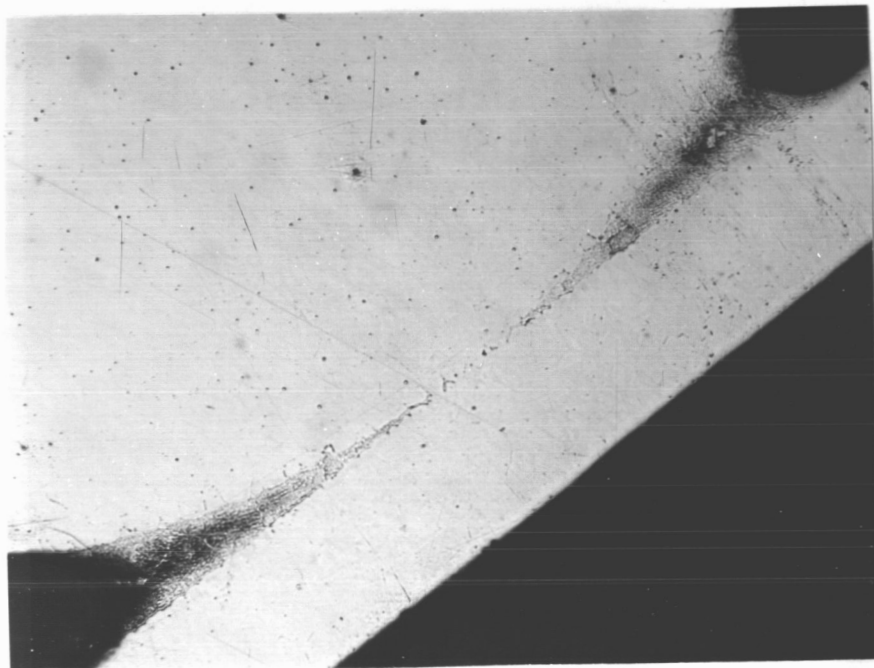
formed between the wire and the flat plate. It should be noted that parent metal diffusion was virtually non-existent. Comparison of the specimens brazed with the .010 diameter alloy wire with the .013 diameter alloy wire showed no appreciable difference. Based on the results, no further effort was undertaken with the Nicoro 80 alloy relative to establishing brazing parameters. Two groups of specimens were initially brazed utilizing the Engaloy 238 and 255 alloys at $1825 \pm 25^\circ\text{F}$. Review of the micro-cross-sections indicated that braze material had not wetted the surface properly with either alloy. An additional set of specimens were then brazed at $1900 \pm 25^\circ\text{F}$ which improved the wettability of both alloys comparable to that achieved with the Nicoro 80 alloy. Figures 4 and 5 show representative micro-cross-sections of both alloys at both braze temperatures.

In order to ascertain the strength of the braze joint, the flat plate specimens were clamped in a fixture and a load applied to the wire loop through a Tinius-Olsen tensile test machine and the results recorded. A tabulation of the test results is provided in Table II.

Review of the failed specimens revealed that in each case failure was due to tearing of the simulated bladder shell (.008 thick 304 material) rather than a failure of the braze material itself. The failures which occurred were a duplication of those experienced with copper brazed specimens. The breakaway loads at which the failure of the specimens occurred was, in general, higher than those experienced with copper indicating that all of the candidate alloys exhibited strengths at least equivalent to copper braze if not better. A picture of a typical specimen failure is shown in Figure 6.



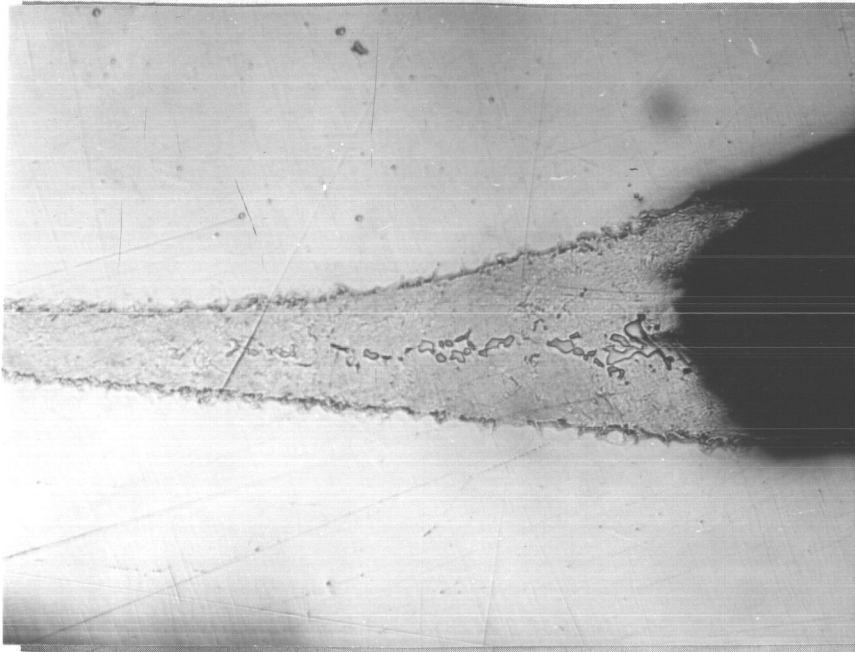
Braze Temperature 1825°F
Magnification 200X



Braze Temperature 1900°F
Magnification 100X

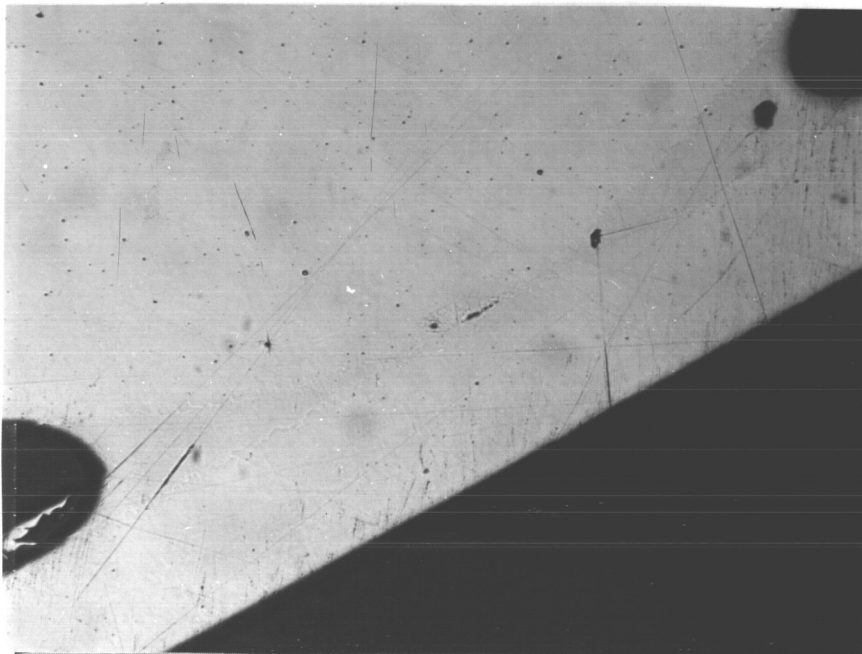
Micro Cross Sections of Specimens
Brazed with Engaloy 238 Alloy

FIGURE 4



Braze Temperature 1825°F

Magnification 200X



Braze Temperature 1900°F

Magnification 100X

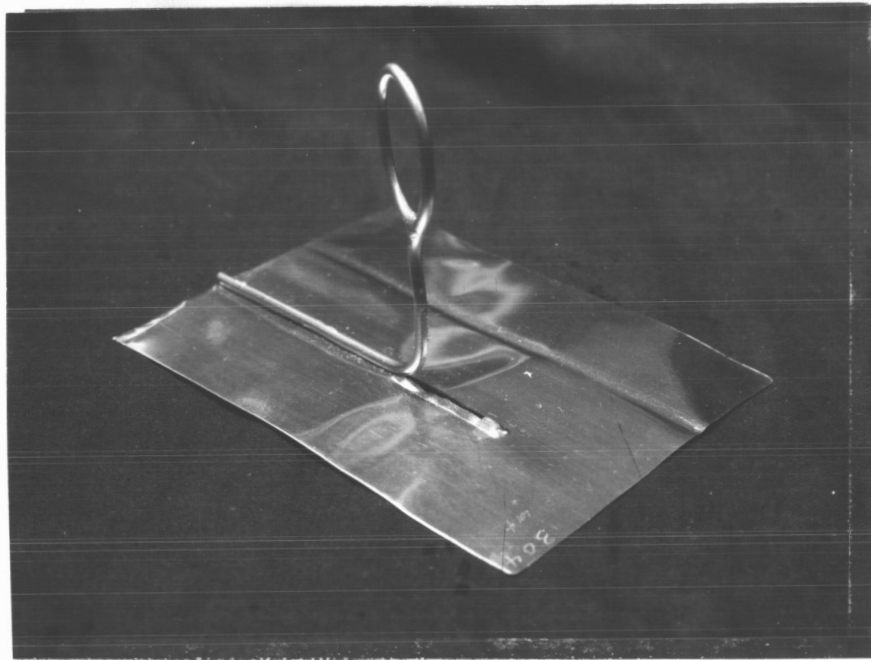
Micro Cross Section of Specimens
Brazed with Engaloy 255 Alloy

FIGURE 5

TABLE IIPeel Specimen Test Results

<u>Specimen S/N</u>	<u>Braze/ Alloy</u>	<u>Braze Wire Dia./in.</u>	<u>Braze Temp./°F</u>	<u>Break- away Load/lbs.</u>	<u>Run Load/lbs.</u>
1	Nicoro 80	.010	1825	216	130/140
2	"	.010	"	174	"
3	"	.013	"	262	"
4	"	.013	"	286	"
5	Engaloy 238	.010	"	224	140/160
6	"	.010	"	232	140/160
7	"	.013	"	*	*
8	"	.013	"	232	160/180
9	Engaloy 255	.010	"	*	*
10	"	.010	"	88*	80/80*
11	"	.013	"	232	210/200
12	"	.013	"	238	150/170
13	"	.010	1900	Not Tested	
14	"	.010	"	"	"
15	"	.010	"	"	"
16	"	.010	"	"	"

* Poor braze or no braze achieved due to movement
of the braze wire during the brazing cycle



Flat Plate Test Specimen After Evaluation

FIGURE 6

Based on the foregoing it appeared that each of the candidate alloys was acceptable for use as a braze material in metallic bladder fabrication from both a brazing as well as a strength standpoint.

C. Compatibility Evaluation

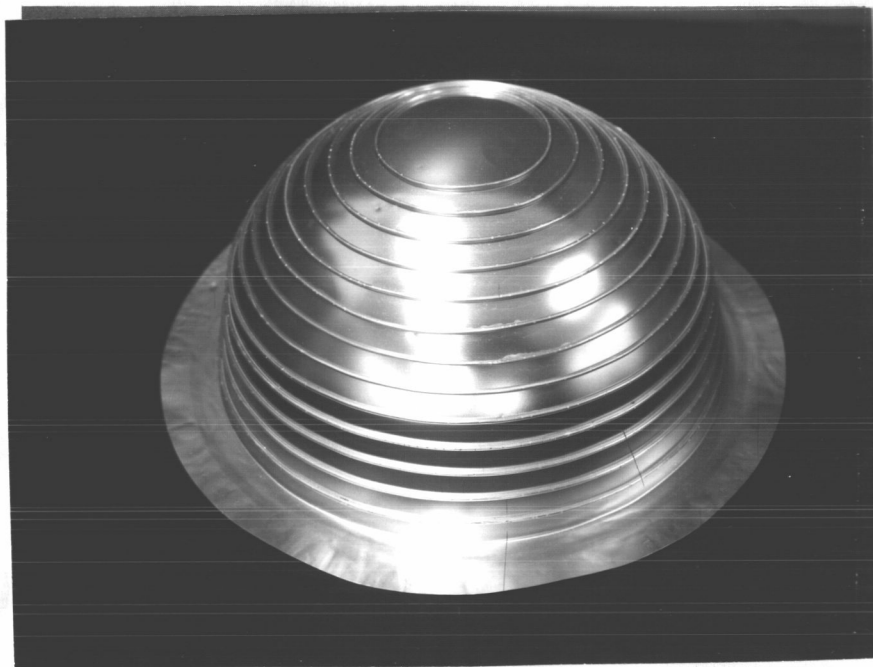
A group of 1/2" x 3/4" specimens were cut from the flat plate braze specimens from each alloy group and forwarded to the Jet Propulsion Laboratory for compatibility testing with both Nitrogen Tetroxide and Hydrazine. The evaluation was conducted at 125°F with the specimens fully immersed in the liquid.

Results of the evaluation indicated that all of the candidate alloys were compatible with both fluids. However, relatively speaking the Engaloy 255 alloy appeared to be most compatible with Hydrazine; whereas the Nicoro 80 was the least.

Based on the foregoing, the Engaloy 255 alloy was chosen as the alloy to be used for the structural bladder model evaluation.

D. Structural Bladder Model Study

Two (2) 11.5 inch diameter structural bladder models were fabricated utilizing the Engaloy 255 alloy to attach .094 diameter 308 stainless steel hoop reinforcing wires to an .008 inch thickness 304L stainless steel bladder shell. A photograph of a representative bladder is shown in Figure 7.



Structural Bladder Model

FIGURE 7

The units were mounted in a water pressurized rig and tested to destruction. A picture of the test set up is shown in Figure 8.

The S/N 1 unit achieved four (4) complete reversals prior to failure; whereas the S/N 2 unit achieved three (3) reversals. Failure is defined as any detectable leakage. In each case failure occurred in the bladder shell and was in no way associated with the braze material. It should be noted that the performance of the bladder was typical for this configuration as similar performance has been recorded in the past with the same configuration bladder where copper was used as the braze material.

Actuation pressures were in the 3 to 5 psi range initially, increasing to the 7-10 psi range for the later reversals. This again, compared favorably with the experience of copper brazed bladders. A series of photographs, Figures 9A through 9F of the S/N 1 unit illustrates the condition of the bladder at various stages of the testing.

A photograph of the micro-cross-section of typical sections taken from each of the units after testing, Figure 10 A, B, revealed that results comparable to those obtained with the flat plate specimens had been achieved with respect to the fillet formation. However, the overall appearance of the units indicated that an increase in brazing temperature was warranted in order to improve the flow characteristics of the alloy such that a more even and uniform fillet would form on both sides of the reinforcing wires. Hence, it appears that increasing the braze temperature to $1950 \pm 25^{\circ}\text{F}$ will achieve the desired results.



Bladder Reversal Rig Test Set Up

FIGURE 8



A

S/N-1 Unit
Partially reversed
through the initial
reversal



B

S/N-1 Unit
After reversal No.1

Gold Braze Structural Bladder Testing

FIGURE 9



C

S/N-1 Unit
After reversal No. 2

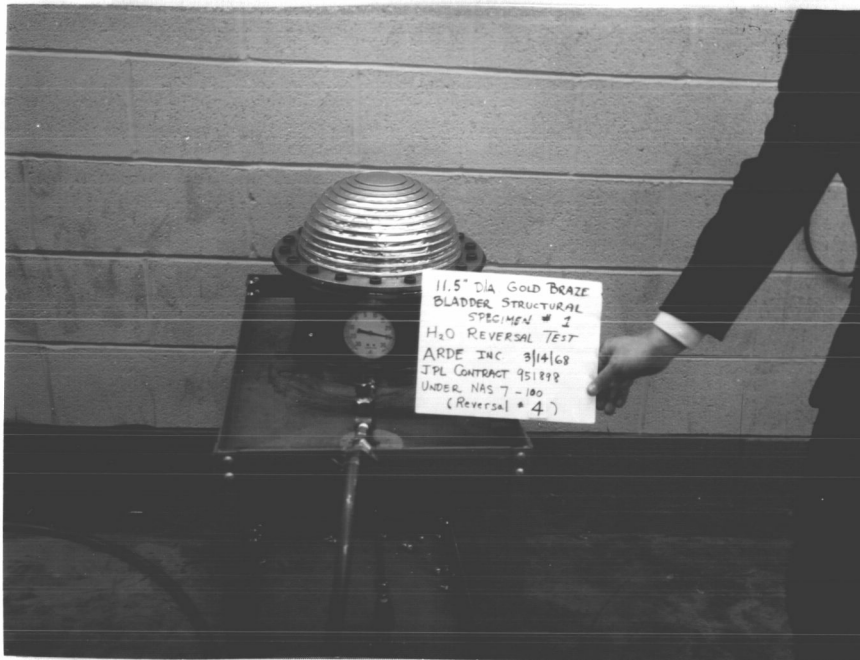


D

S/N-1 Unit
After reversal No. 3

Gold Braze Structural Bladder Testing

FIGURE 9



E

S/N-1 Unit
After reversal No.4

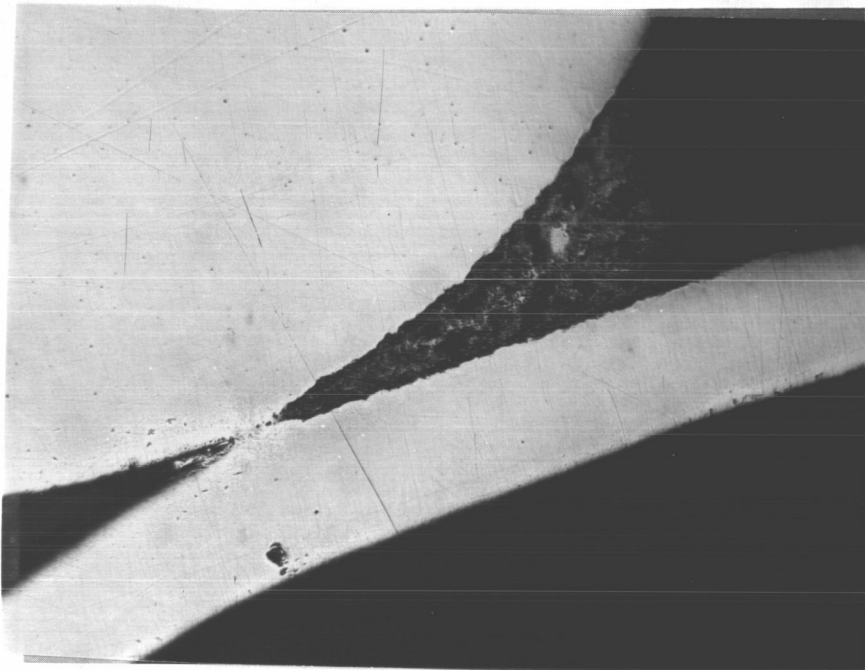


F

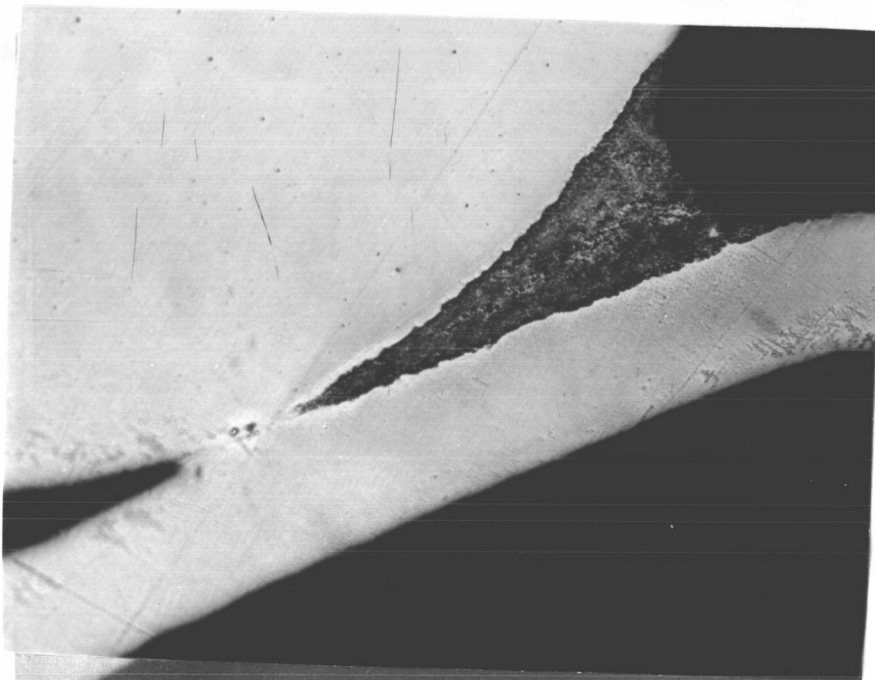
S/N-1 Unit
At failure

Gold Braze Structural Bladder Testing

FIGURE 9



A
S/N-1 Unit
Magnification 100X



B
S/N-2 Unit
Magnification 100X

Micro Cross Sections
Structural Bladder Models Brazed with Engaloy 255 Alloy

FIGURE 10

V CONCLUSIONS

1. The use of the Engaloy 255 gold braze alloy for the braze material which attaches the hoop reinforcing wires to the bladder shell in no way compromised the physical performance of the bladder.
2. The alloy, based on the testing conducted at JPL, appeared to be compatible with both Nitrogen Tetroxide and Hydrazine.

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